Extinction-to-backscatter ratios of lofted aerosol layers observed during the first three months of CALIPSO measurements

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Abstract

Case studies from the first three months of the Cloud and Aerosol Lidar and Infrared Pathfinder Spaceborne Observations (CALIPSO) measurements of lofted aerosol layers are analyzed using transmittance [*Young*, 1995] and two-wavelength algorithms [*Vaughan et al.*, 2004] to determine the aerosol extinction-to-backscatter ratios at 532 and 1064 nm. The transmittance method requires clear air below the layer so that the transmittance through the layer can be determined. Suitable scenes are selected from the browse images and clear air below features is identified by low 532 nm backscatter signal and confirmed by low depolarization and color ratios.

The transmittance and two-wavelength techniques are applied to a number of lofted layers and the extinction-to-backscatter ratios are compared with values obtained from the CALIPSO aerosol models [*Omar et al.*, 2004]. The results obtained from these studies are used to adjust the aerosol models and develop observations based extinction-to-backscatter ratio look-up tables and phase functions. Values obtained by these techniques are compared to S_a determinations using other independent methods with a goal of developing probability distribution functions of aerosol type-specific extinction to backscatter ratios. In particular, the results are compared to values determined directly by the High Spectral Resolution Lidar (HSRL) during the CALIPSO CloudSat Validation Experiments (CCVEX) and S_a determined by the application of the two-wavelength lidar Constrained Ratio Aerosol Model-fit (CRAM) retrieval approach [*Cattrall et al.*, 2005; *Reagan et al.*, 2004] to the HSRL data. The results are also compared to values derived using the empirical relationship between the multiple-scattering fraction and the linear depolarization ratio by using Monte Carlo simulations of water clouds [*Hu et al.*, 2006].

Given a solution of the particulate backscatter at 532 nm $\beta_{532,p}$, the two-wavelength method uses a least squares method to minimize the difference between the attenuated total backscatter measurement at 1064 nm, B_{1064} and the right hand side of eq. (1).

$$B_{1064}(r) = \left(\beta_{m,1064}(r) + \beta_{p,1064}\right) \cdot T^2_{p,1064}(r)$$
$$= \left(\beta_{m,1064}(r) + \underline{\chi} \cdot \beta_{p,532}(r)\right) \cdot \exp\left(-2 \cdot \underline{S_{1064}} \cdot \underline{\chi} \cdot \gamma_{532}(r)\right)$$

(1)

Note that the only unknowns (underlined) in eq.(1), the extinction to backscatter ratio at 1064 nm, S_{1064}, and the color ratio, χ (defined as $\beta_{1064,p}/\beta_{532,p}$), are both intensive properties defined by the layer composition, size distribution, and shape of its constituent particles. So long as these characteristics do not vary substantially, we can, and do make the assumption that S_{1064} and χ are constant within the layer. The method is applicable whenever there is a reliable S_{532} value such as in the CALIOP S_a selection algorithm for attached tropospheric aerosol layers.

Two scenes: off the west coast of Africa (Fig.1) and in the south Atlantic both lofted to 3-5 km were analyzed and yielded extinction to backscatter ratios (532-,1064-nm) of (28,33 sr) and (59, 60 sr), respectively. An examination of the averaged layer depolarization and color ratios identifies these layers as dust and smoke aerosols.
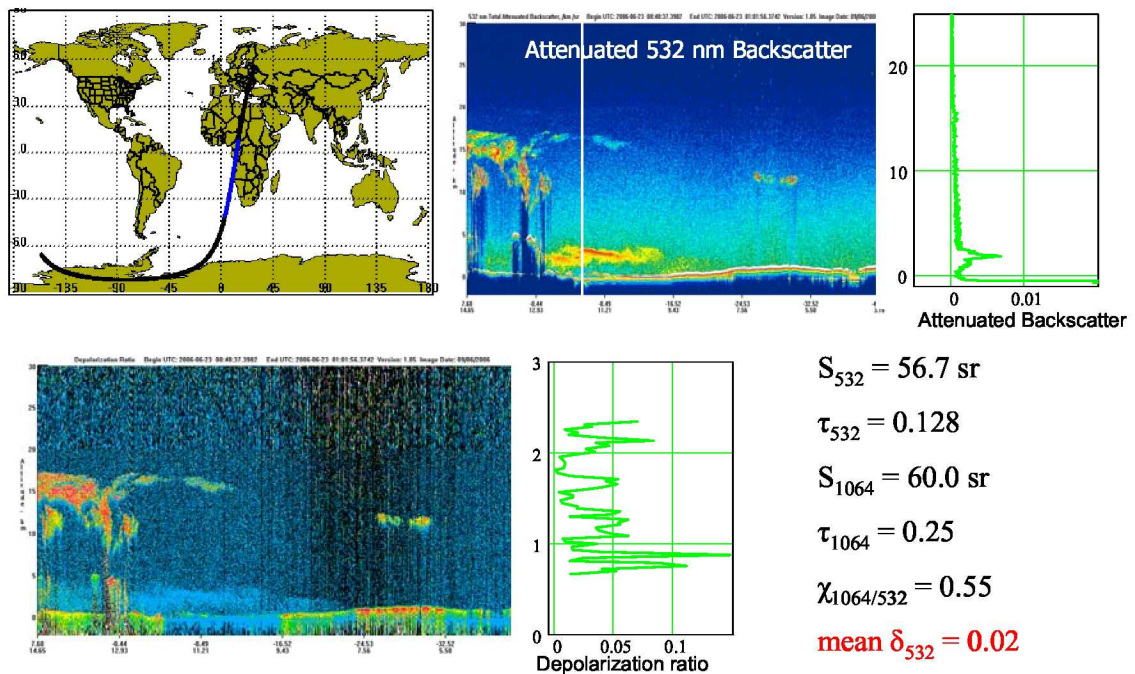

$S_{532} = 56.7$ sr

$\tau_{532} = 0.128$

$S_{1064} = 60.0$ sr

$\tau_{1064} = 0.25$

$\chi_{1064/532} = 0.55$

mean $\delta_{532} = 0.02$

Figure 1. An elevated smoke layer of the west coast of Africa observed by CALIOP on June 23, 2006.

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